NRA
TIM #3

METRON AVIATION

Technologies Enabling All-Weather Maximum Capacity by 2020

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Presented at NASA Ames Research Center

Moffett Field, CA

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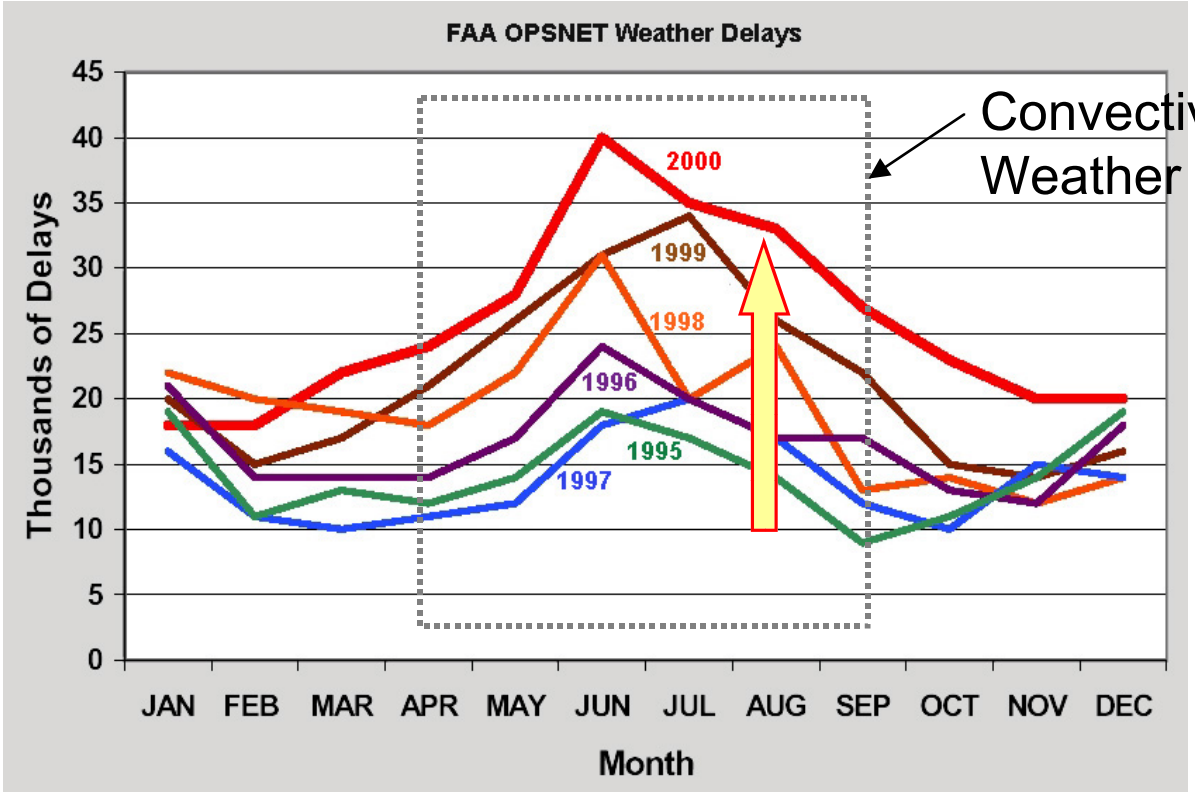
Agenda:

- Need for All-Weather Capabilities
- Core Ideas for the All-Weather Capacity-Increasing Concept
- Benefit Mechanisms from the Core Ideas
- Self Assessment Plans for the Next Phase of Project
- Conclusions

General: The NAS is not Robust to Weather Disturbances



Weather related delays are currently increasing, especially during summer "Convective Weather Season"

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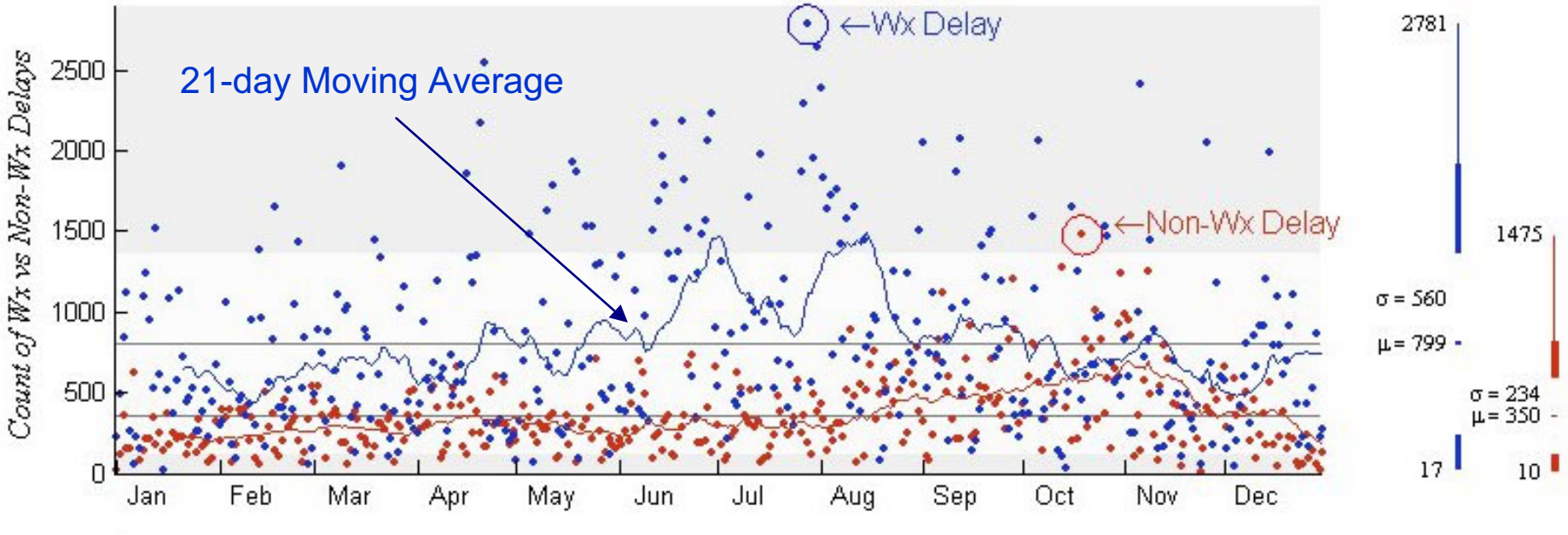
Specific: The NAS is not Robust to Weather Disturbances

2000 FAA OPSNET Data



While the effect generally maximizes during the Convective Weather Season, everyday is different!

The Weather related Delays are significantly higher than the Non-Weather Related Delays

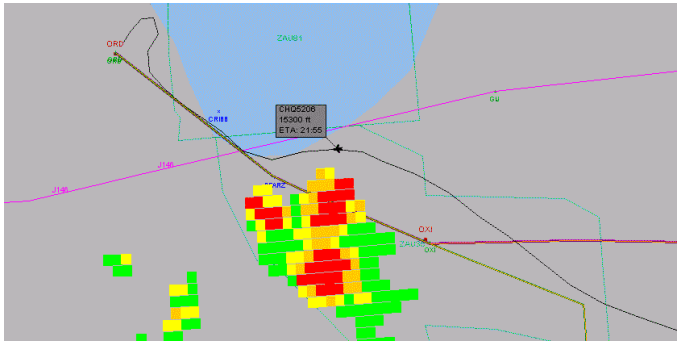
Problem Situations: Weather Reduces Capacity

Surface

1. Snow, Ice, Slush, or Water on Runway
2. Low Visibility Produced by Fog, Rain, Snow, or other Conditions
3. Aircraft Requiring De-icing
4. Shifting Wind Direction Changes the Runway Configuration
5. Large Scale Weather System Causes Weather-Related GDP/MIT Constraints at Multiple Airports Simultaneously

Problem Situations: Weather Reduces Capacity

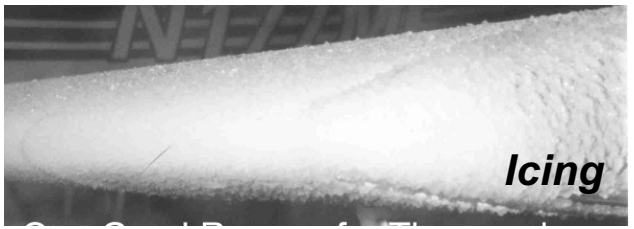
Terminal/Transition



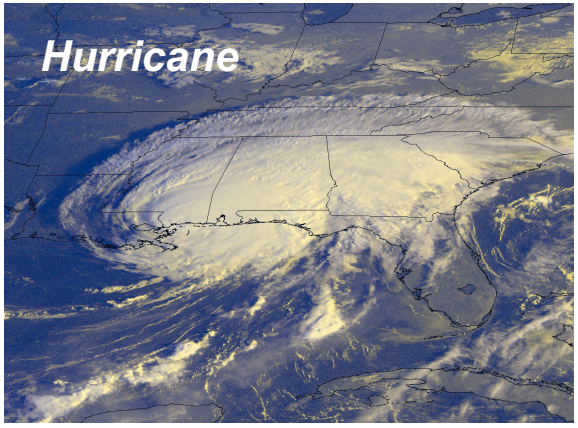
1. Isolated Weather Cell Affecting an Arrival or Departure Stream
2. Weather Constraints Affecting Coupled Arrival/Departure Streams
3. Weather Constraints Initiating Arrival/Departure Strategic Trade-offs (30-60 Min. Lead Time for Planning)
4. Weather Constraints Impacting Arrival Airspace Capacity (2-4 Hr. Planning Horizon)

Problem Situations: Weather Reduces Capacity

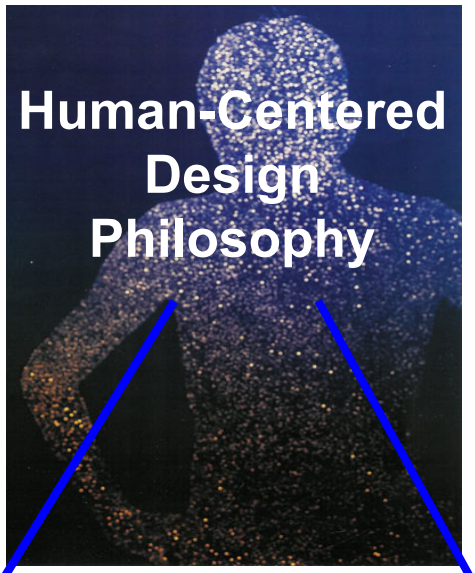
En Route



1. Unanticipated Clear Air Turbulence
2. Icing Forces Aircraft Deviations
3. Convective Weather with High Tops and Convection
4. Multiple Clusters of Weather Cells within the Same Center
5. Impassable Line of Weather from Canada to South
6. Convective Storm over Midwest where high Density Flows must go around weather
7. Convective Storm covering Northeast
8. Extremely Strong Jet Stream
9. Hurricane in the Southeast
10. Volcanic Ash in Atmosphere



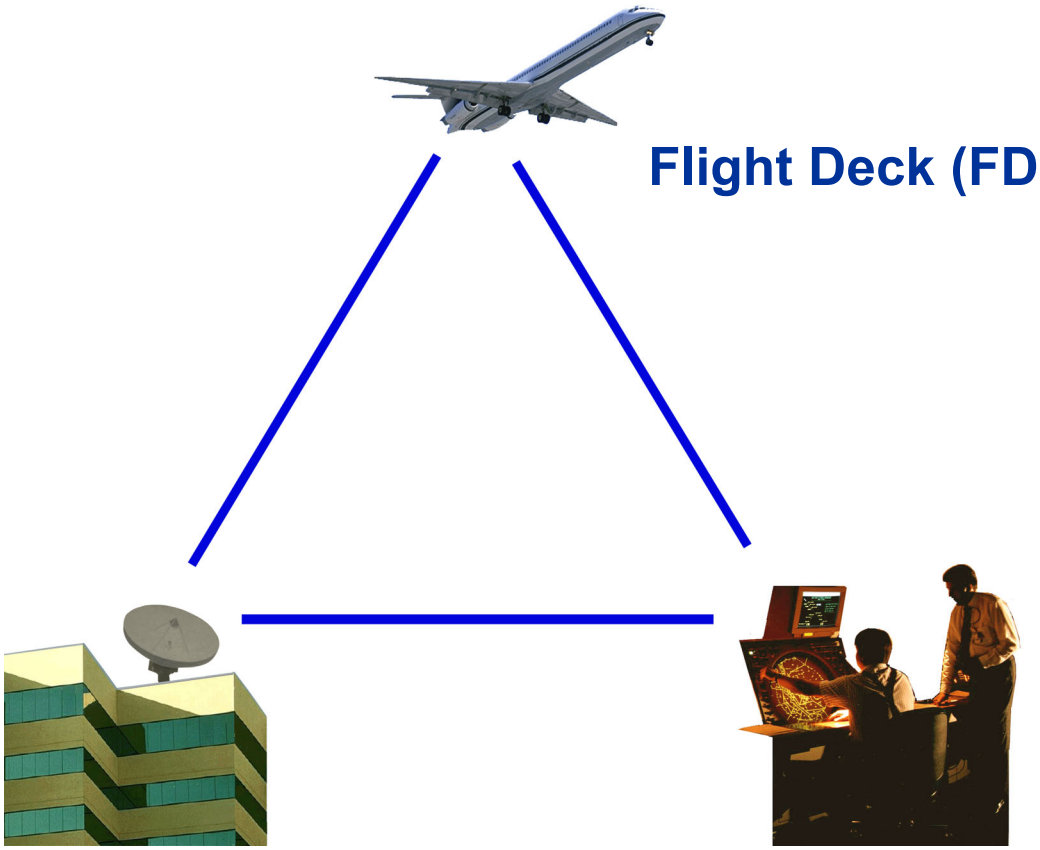
Triad of Philosophies:



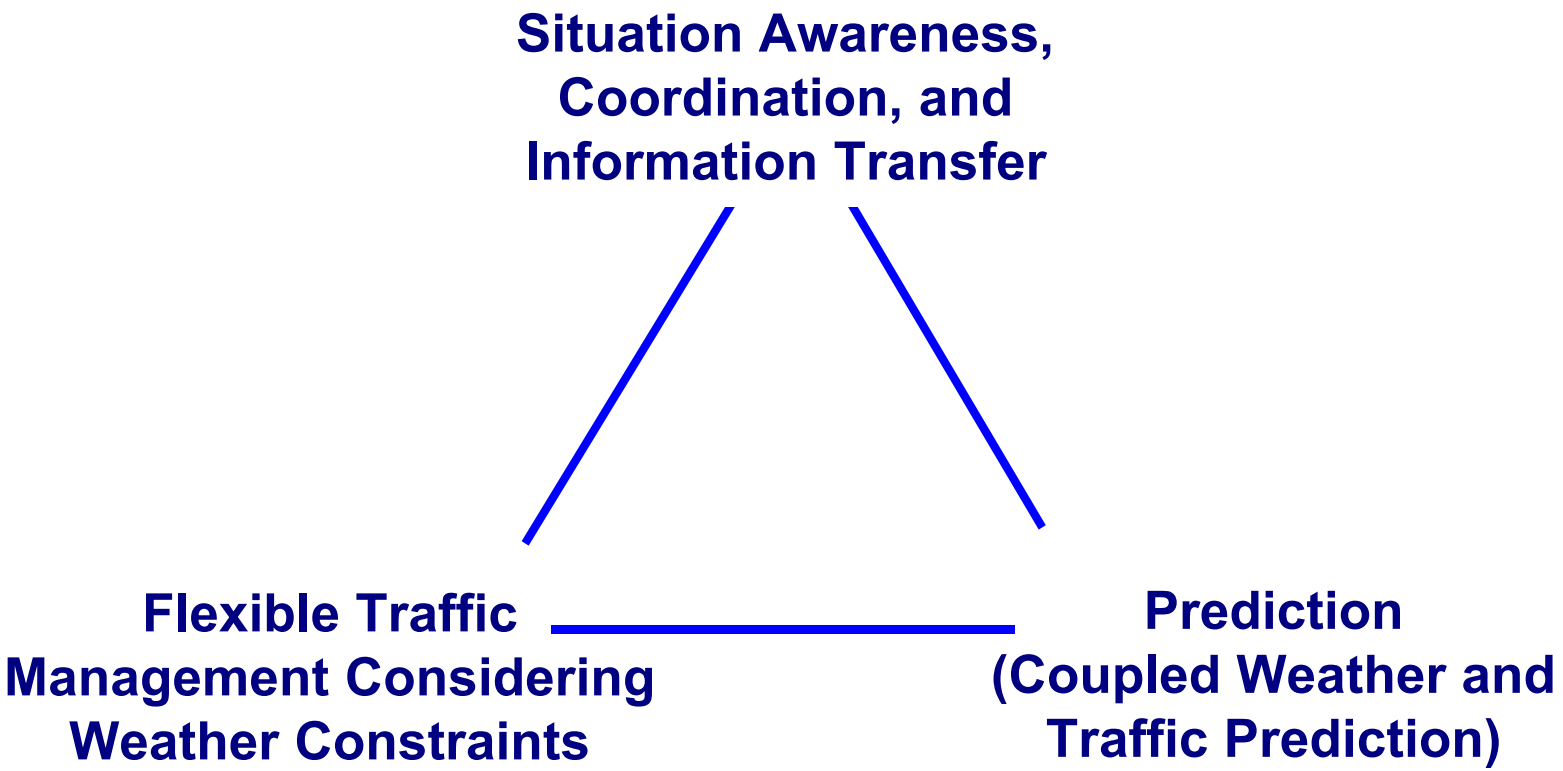
Inter-Disciplinary Design Philosophy

Multi-Domain Philosophy

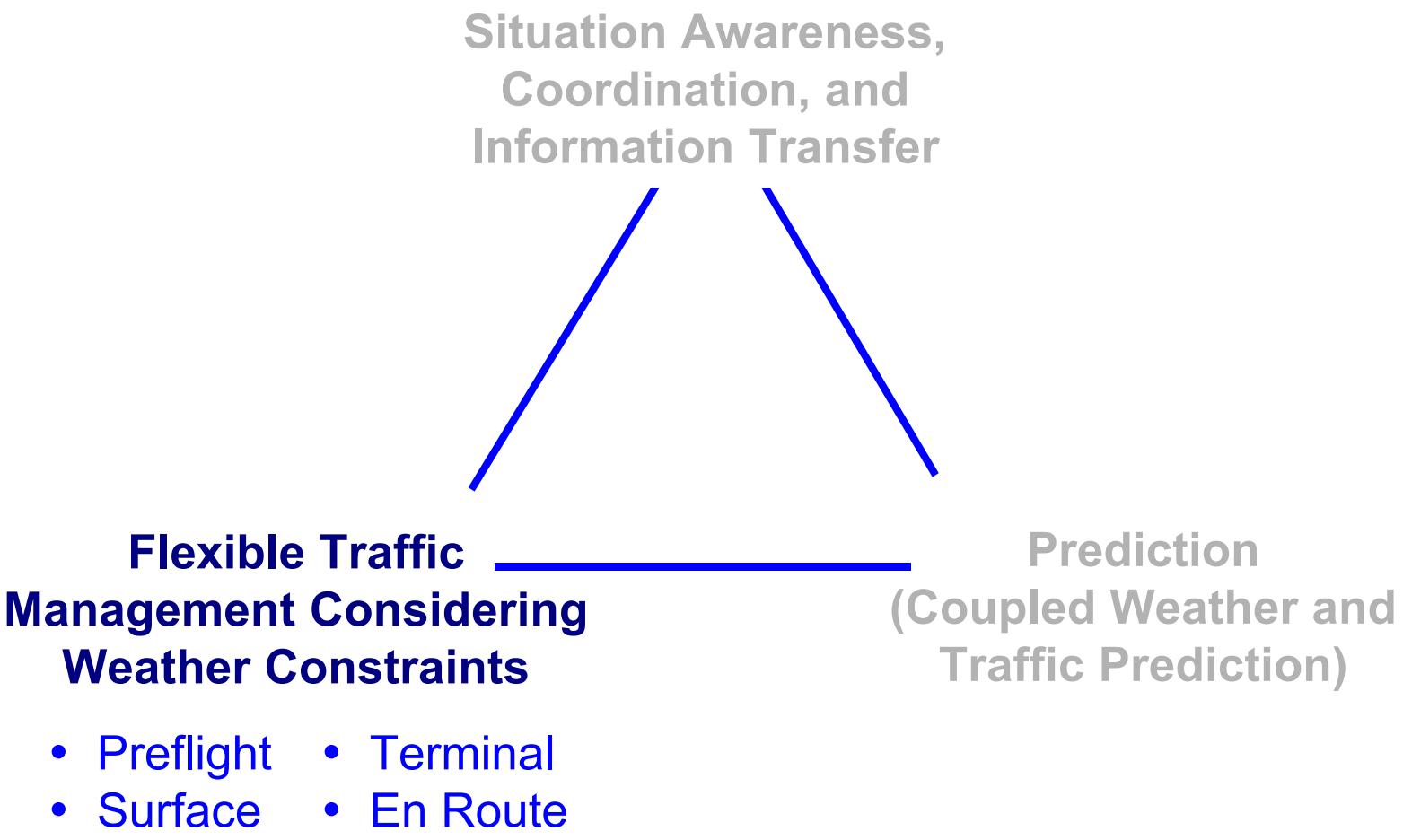
User Triad:


Flight Deck (FD)
Airline Operational Control (AOC)
Air Traffic Service Provider (ATSP)

Core Idea Triad:



Core Idea 1:


Situation Awareness, Coordination, and Information Transfer
Flexible Traffic Management Considering Weather Constraints
Prediction (Coupled Weather and Traffic Prediction)
• Preflight
• Surface
• Terminal
• En Route

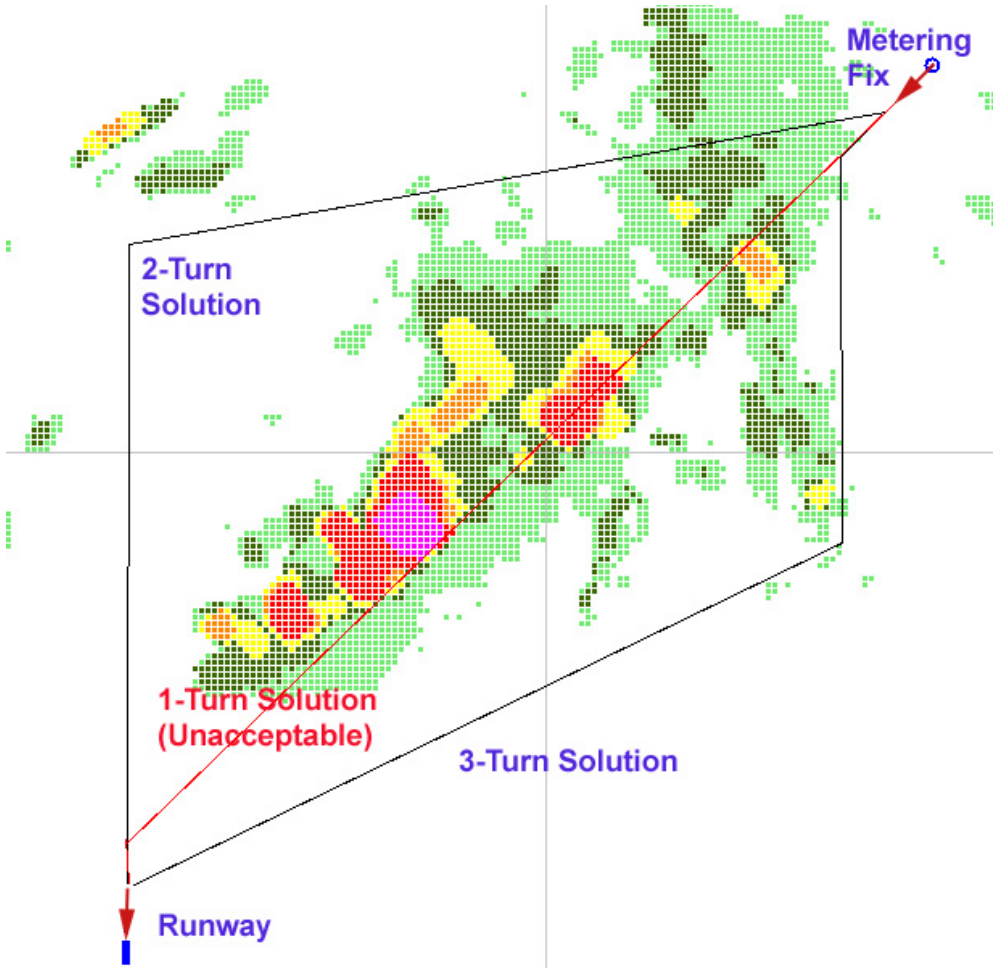
Core Idea 1.1: Pre-Flight Planning to Manage Airport Flow Rates

- Long-Term Probabilistic Weather Forecasts
- GDPs
- Fix-Based GDPs
- Distance-Based 1st Tier, 2nd Tier GDPs
- Cancellations
- User Priorities and Constraints

Core Idea 1.2: Precise Control of Take Off Time to Address Weather Constraints

- Passback of Terminal/Transition airspace weather constraints for departure flights
- Ground Stop and GDP EDCTs in support of SWAP
- APREQs for timing of departure releases for capping / LAADR maneuvers into overhead streams
- EDCT Compliance through SMS, including coordination of de-icing and snow removal vehicles on runways
- Augmented Reality, HUD, and EMM Displays for low and zero visibility conditions

Core Idea 1.3: Weather Avoidance in the TRACON



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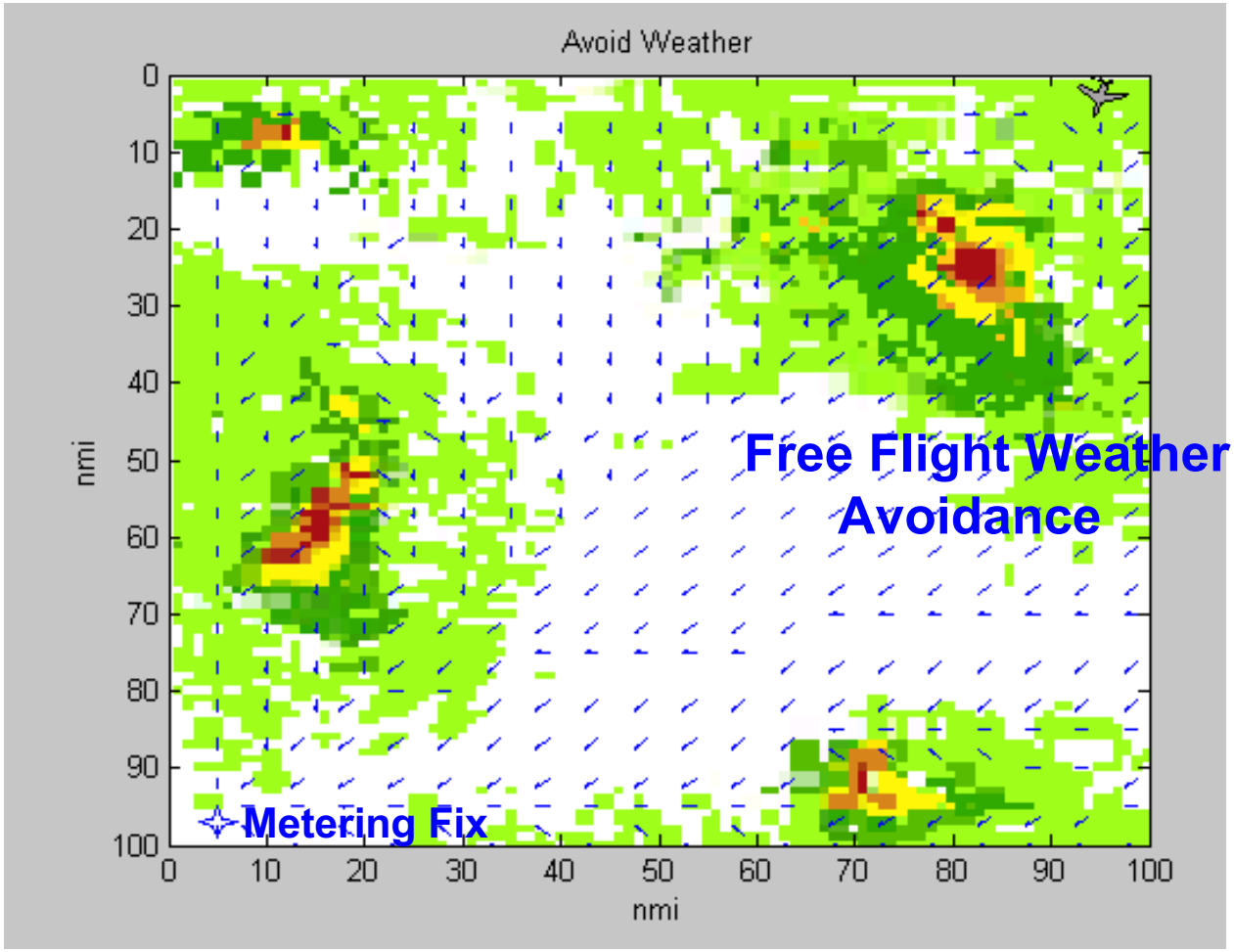
Core Idea 1.4: Weather Avoidance Algorithms for the Transition Airspace



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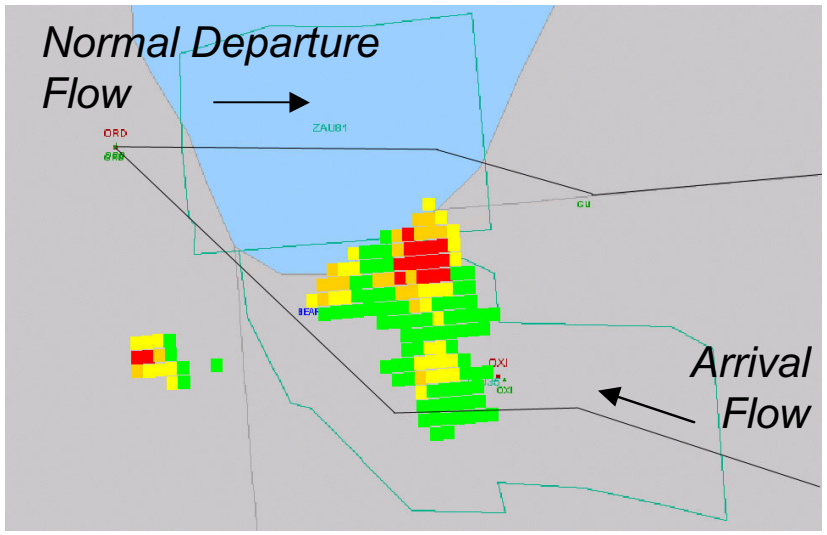
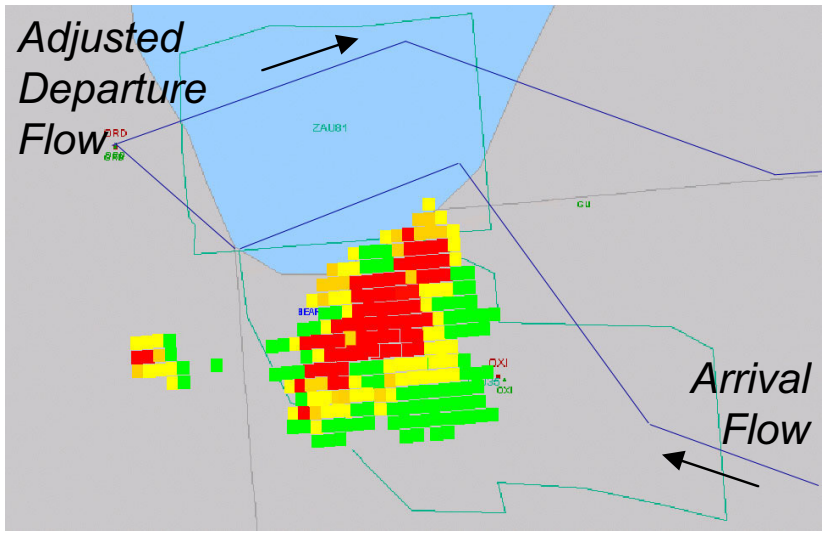
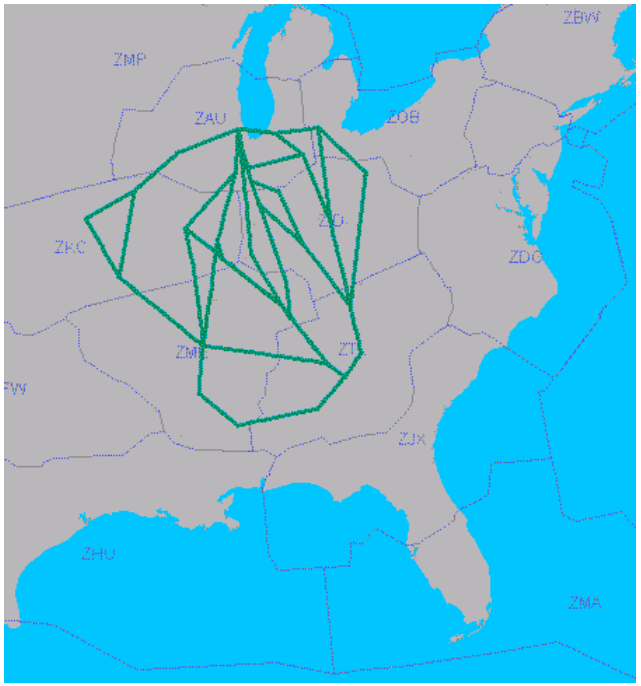


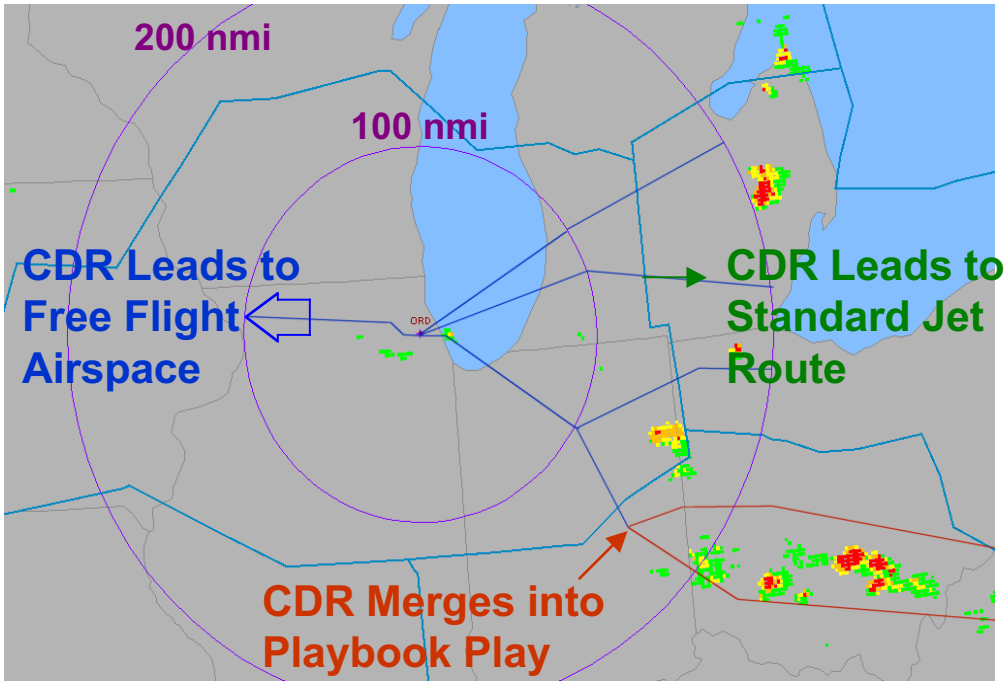


Departure Flow Unaffected by Arrival Flow Weather Avoidance Route

Departure Flow Re-Designed with Arrival Flow Weather Avoidance Route

Core Idea 1.4: Weather Avoidance Algorithms for the Transition Airspace

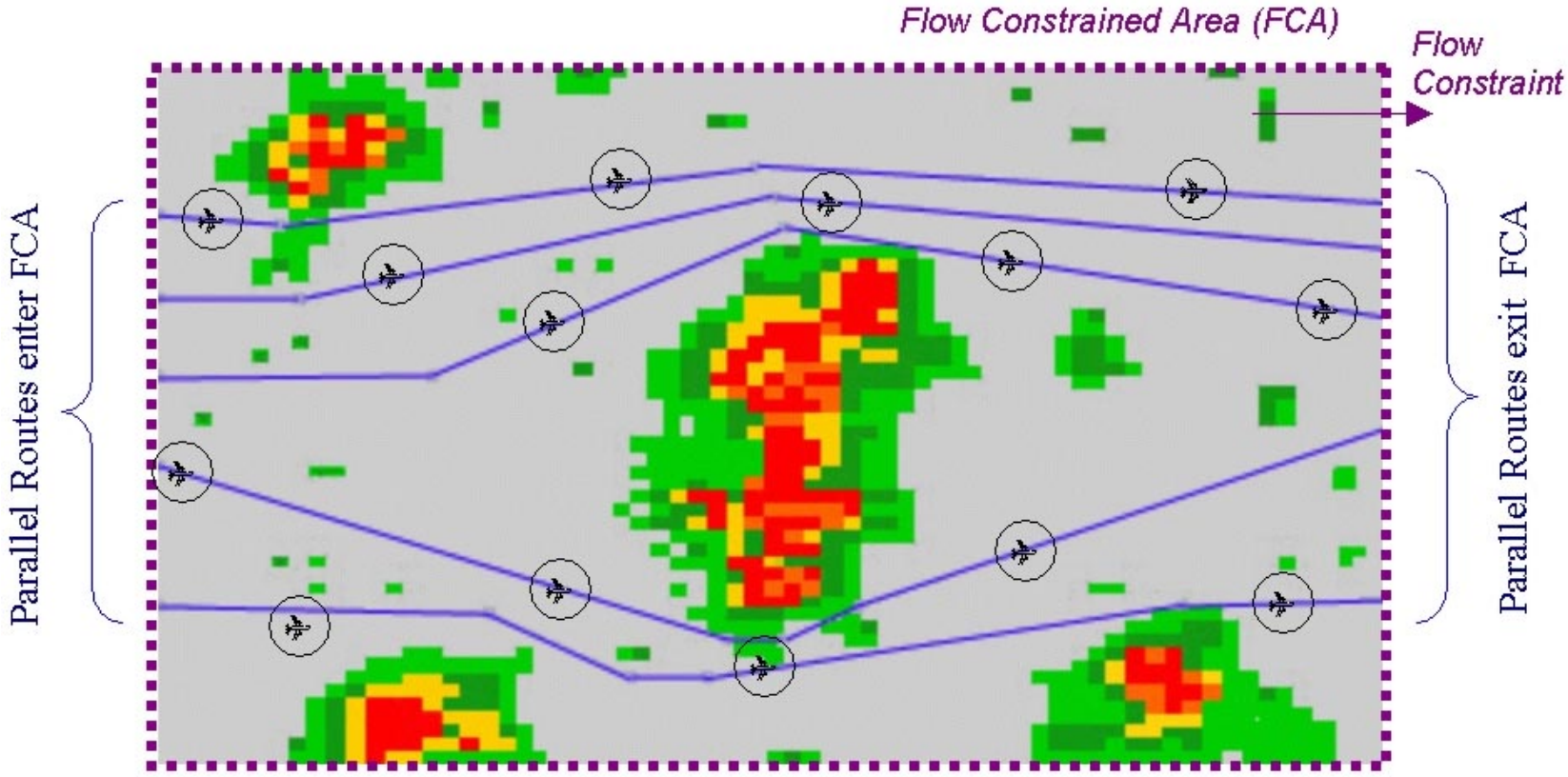




Current CDRs Extend from Departure Airport to Arrival Airport

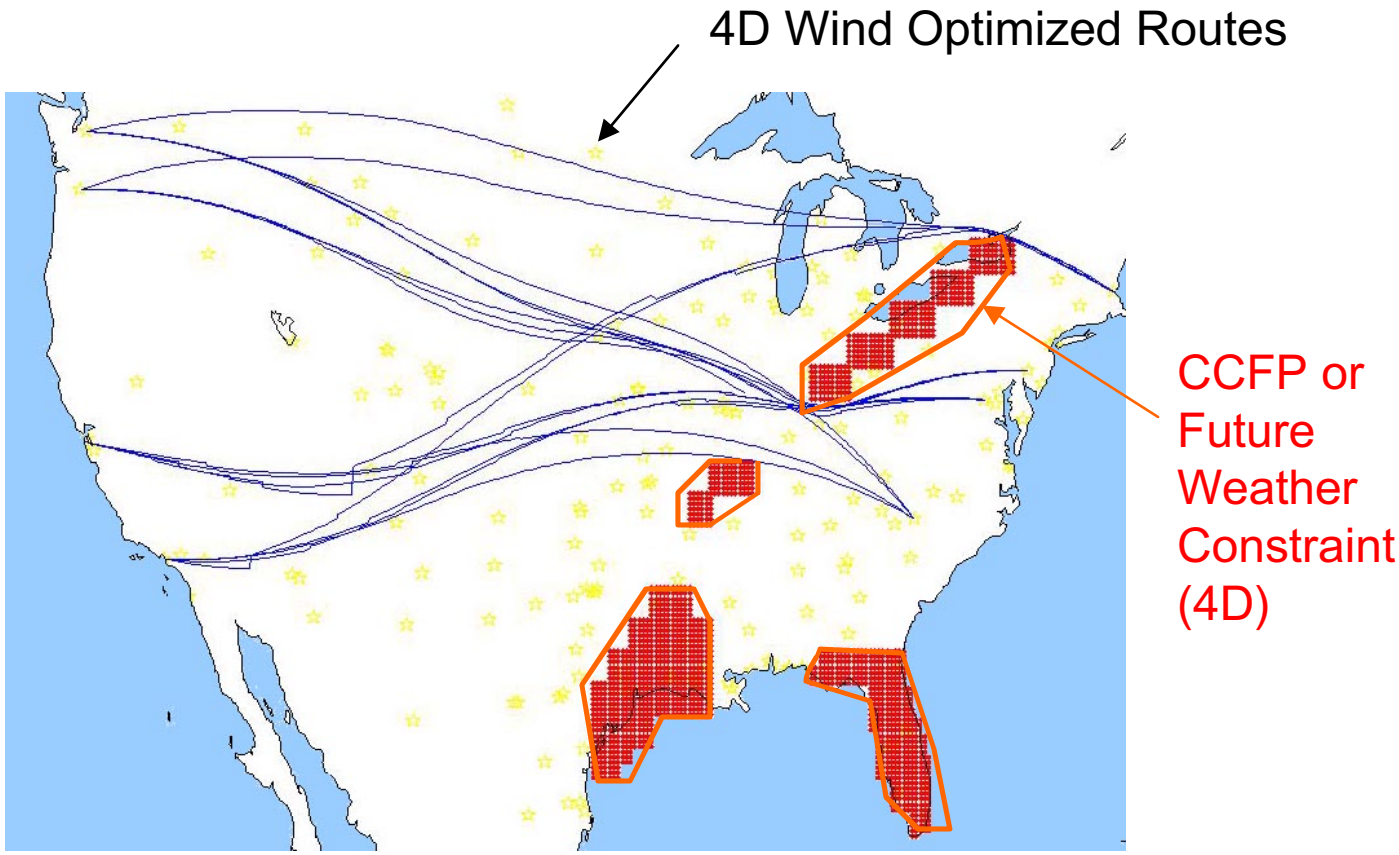
Range-Based CDRs Extend out a Fixed Range and Merge with Free Flight Airspace, Standard Jet Routes, or Playbook Plays

Core Idea 1.5: Weather Avoidance Algorithms for En Route Aircraft



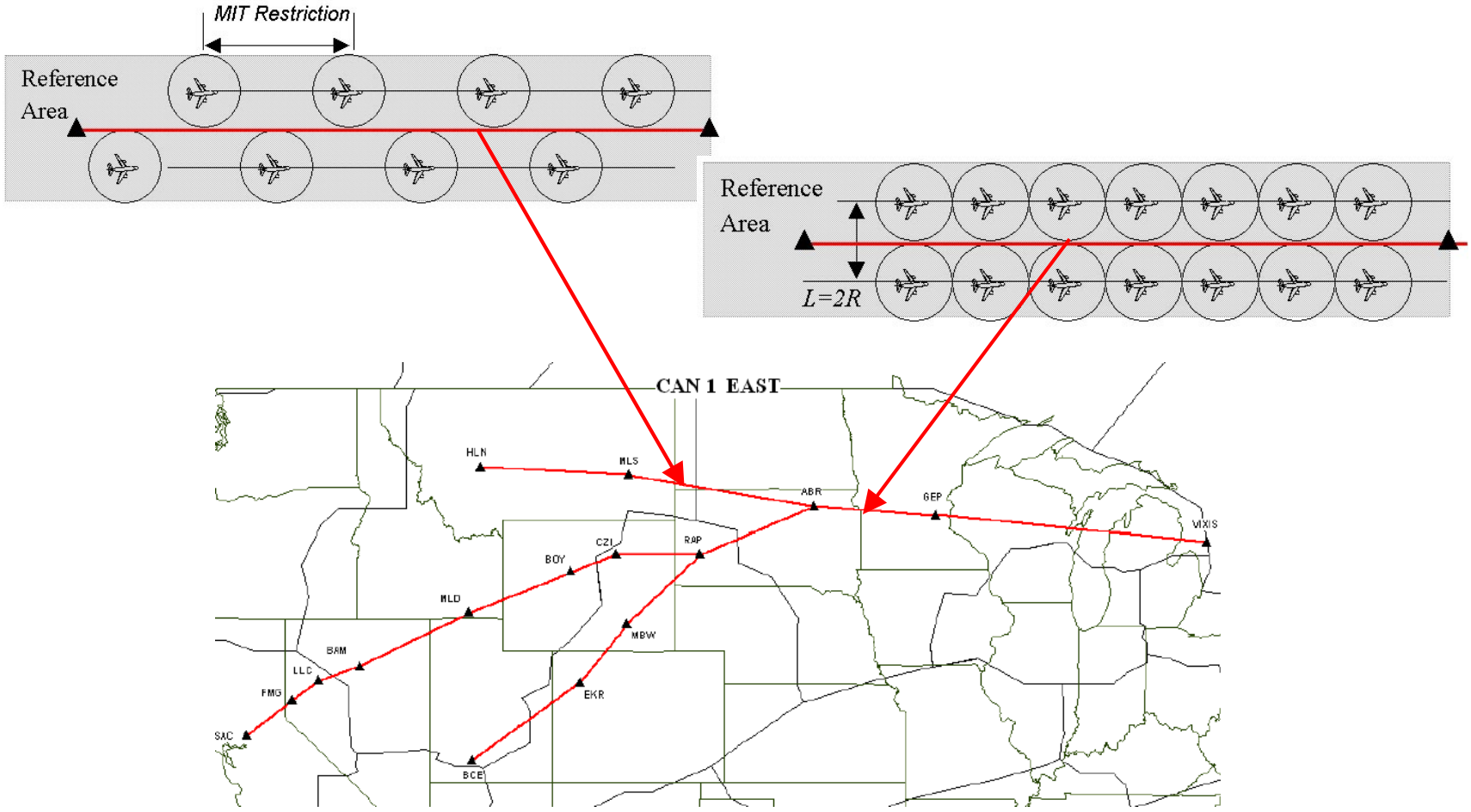
Parallel Routes Dynamically Defined Around Weather Constraints

Core Idea 1.5: Wind-Optimal Free Flight Routes



Method of Jardin (NASA) modified to avoid large Weather Constraints

Core Idea 1.6: Coordination of Large Scale TFM Plans



Parallel Routes Applied to Playbook Plays

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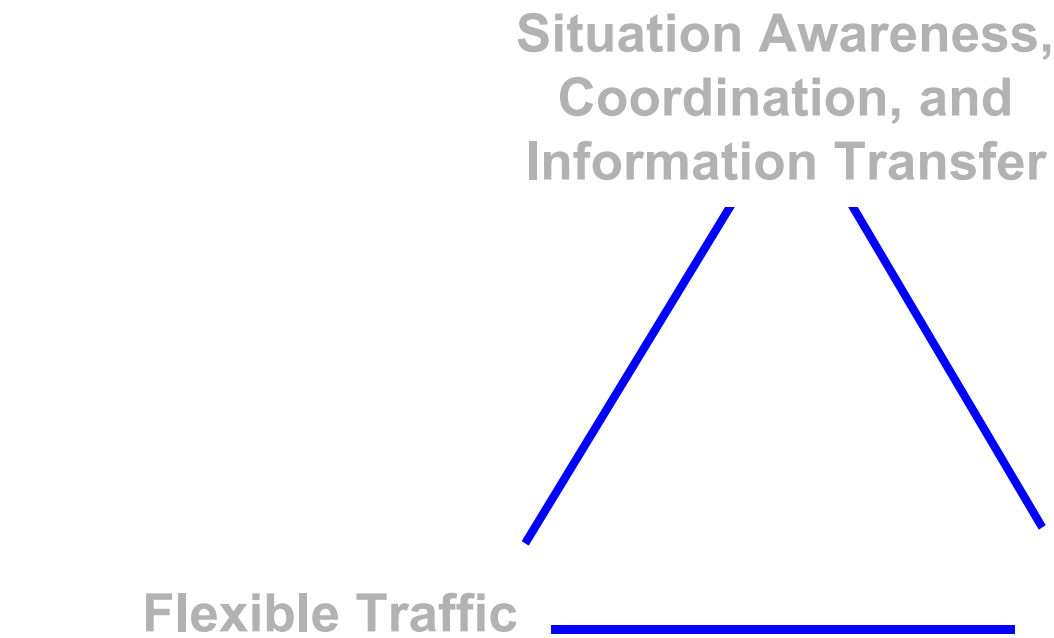
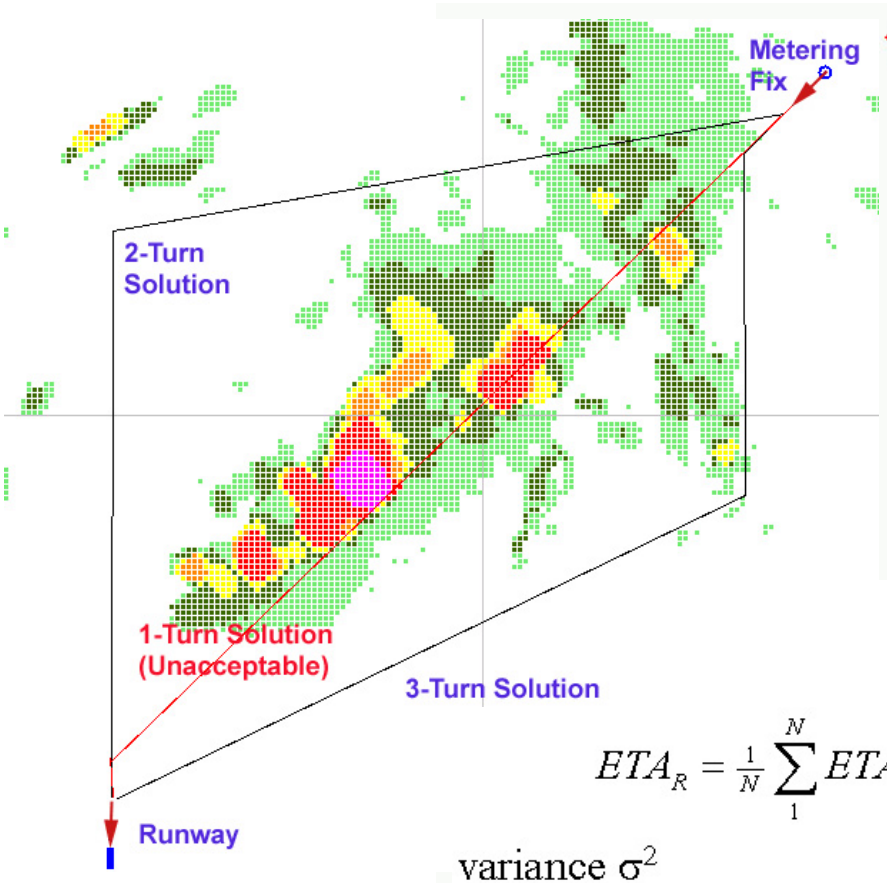
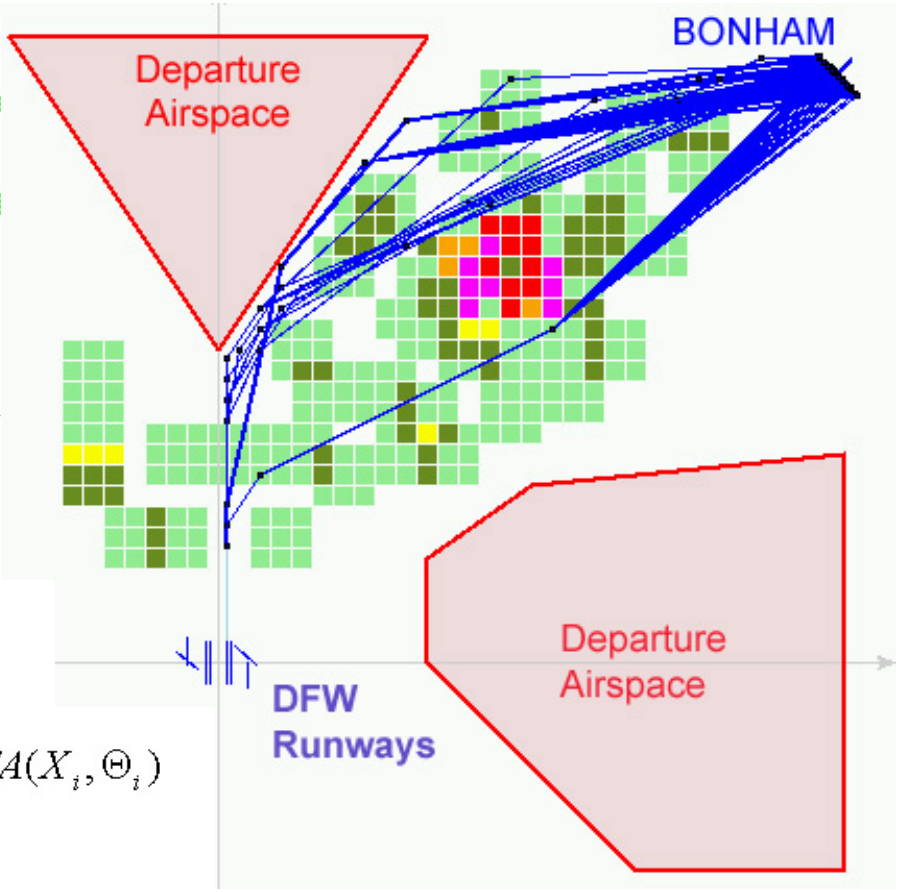
Core Idea 2:



- Estimated Times of Arrival
- Sector Counts
- Flow Rates: AARs and ADRs

Core Idea 2.1: Incorporate Weather Predictions into ETAs





$$ETA_R = \frac{1}{N}\sum_{1}^{N} ETA(X_i, \Theta_i)$$

variance σ^2

$$\sigma^2 = \frac{1}{N}\left[\sum_{1}^{N} ETA(X_i, \Theta_i)^2\right] - ETA_R^2$$

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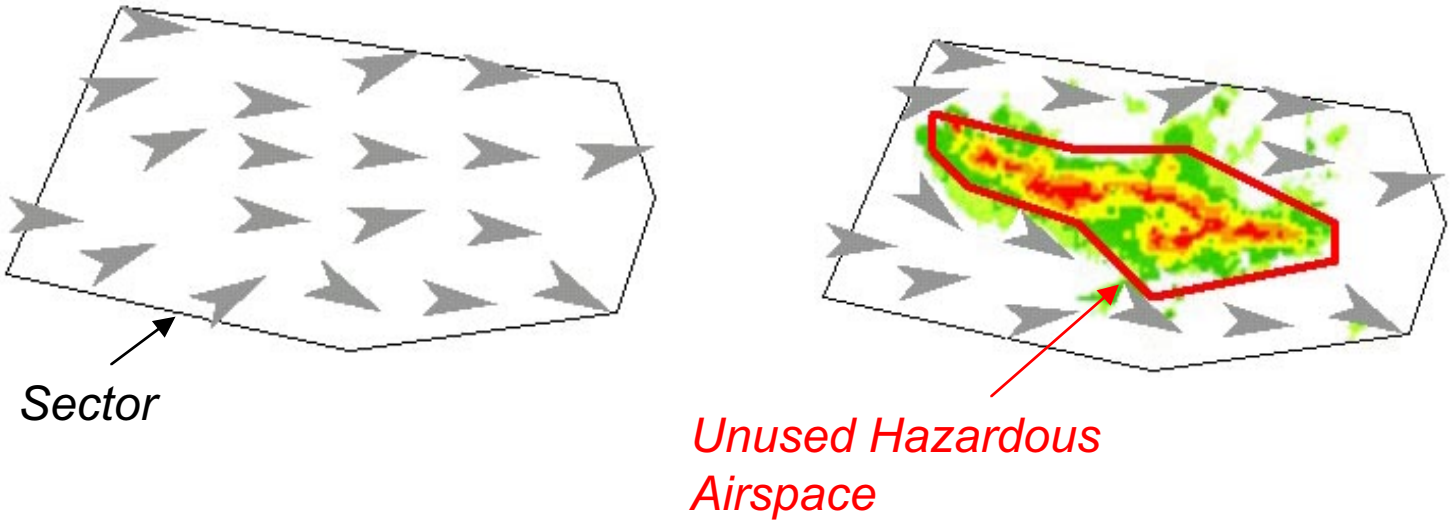
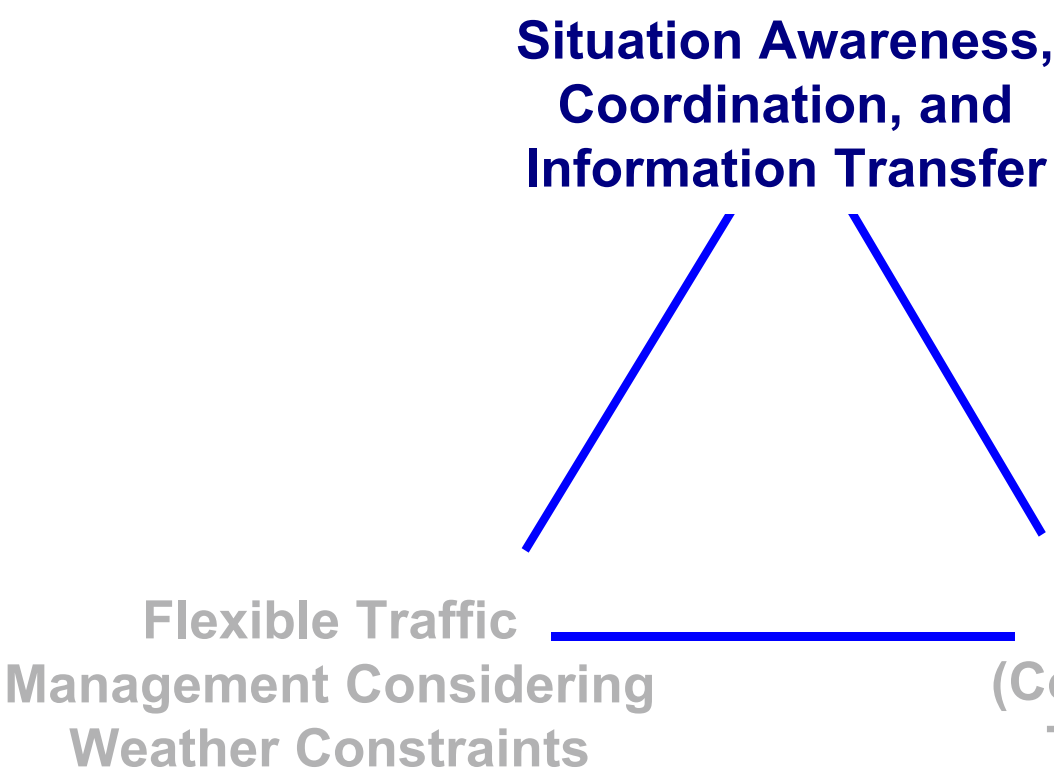
Core Idea 2.2: Sector Demand Predictions and Weather

- Estimate Sector Loads based on Trajectory Predictions that include Weather Constraints
- Dynamically adjust the Sector Load Capacity to account for the amount of Unused Hazardous Airspace Present in the Sector



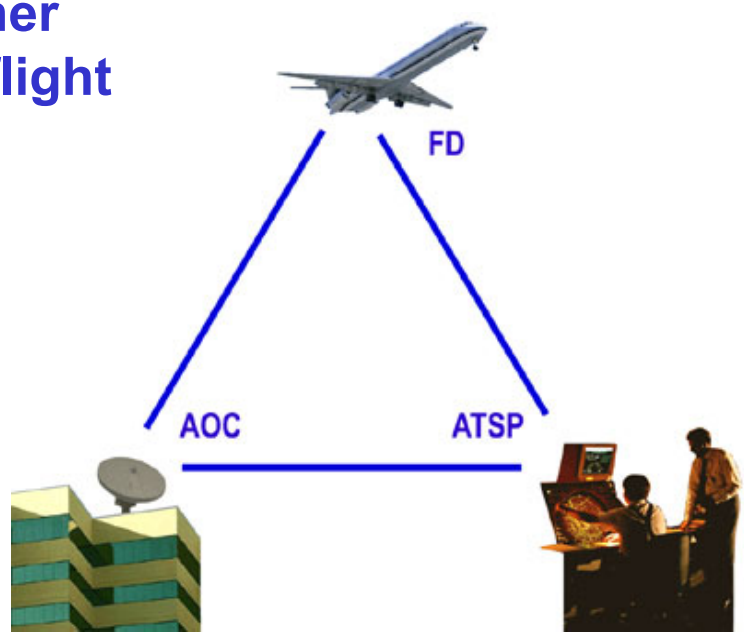
Core Idea 3:



- Coordination of Weather Information
- Shared Situation Awareness
- Coordination of User Goals and Constraints

Core Idea 3.1: Coordination of Weather Information

- **Weather information (actual weather and its effects) from a variety of sources needs to be collected, compared, integrated, fused, coordinated, and distributed.**
- **Information on the surface needs to be combined with information in the air to provide NAS-wide mosaic of weather conditions affecting all phases of flight**
- **Sources include:**
  - MDCRS data
  - PIREPs
  - Radar Data
  - Satellite Data
  - Surface Conditions



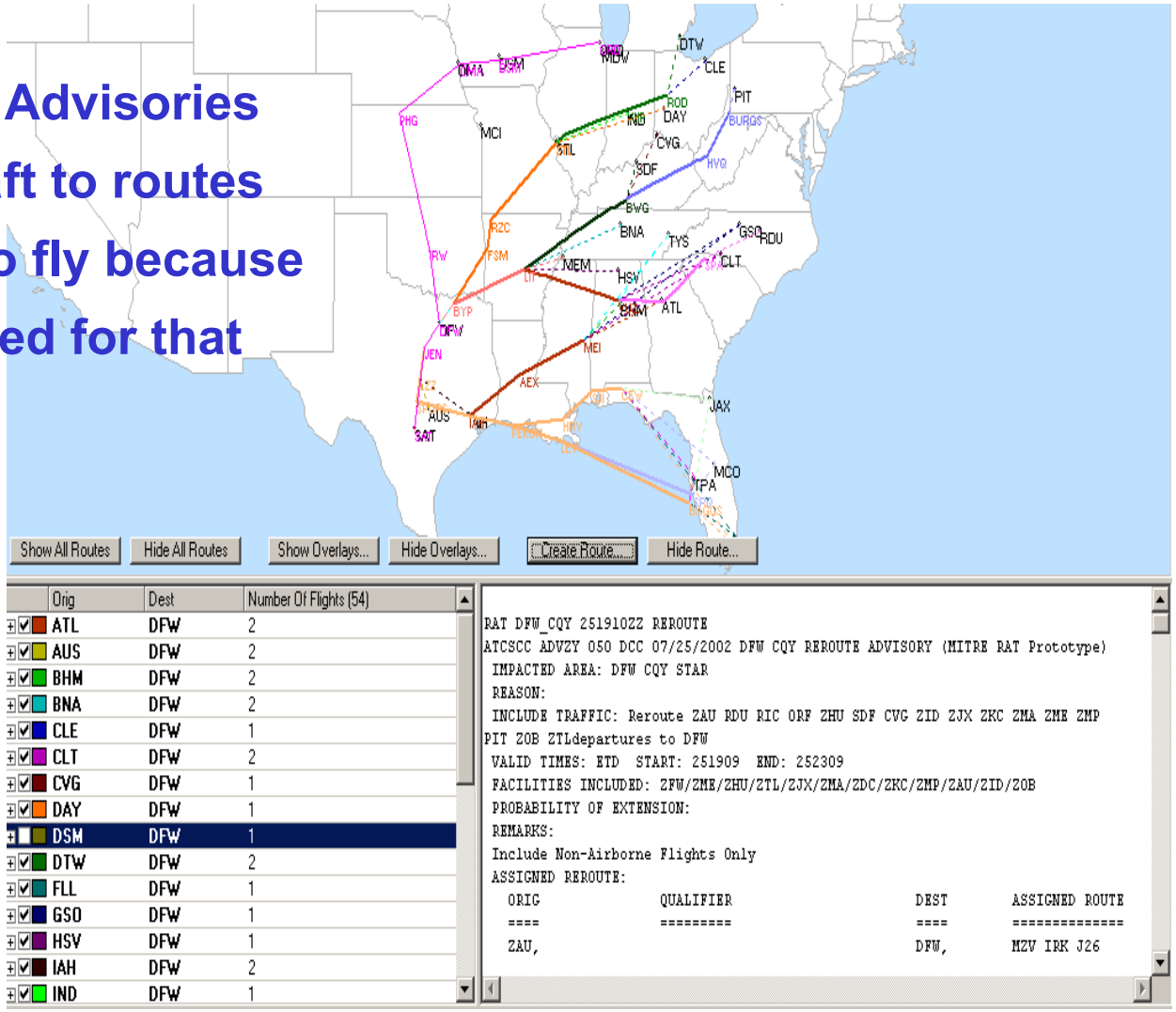
Core Idea 3.2: Shared Situation Awareness

- The User Triad needs to share the same perspective, or awareness, of weather-related information, so that the best strategy for mitigating weather effects can be communicated and coordinated
- Shared awareness can be accomplished through both a common view and a remote perspective view
- Users must have quick and easy access to this shared mode
- A secure NAS state/weather information distribution network and a unique user interface concept are required

Core Idea 3.3: Accommodate NAS User Goals/Constraints

- **Weather Reroute Advisories that assign aircraft to routes they are unable to fly because they can't be fueled for that long a route**

- **E.g., An F100 cannot fly a major reroute DFW to ORD (pink route on the left on map)**

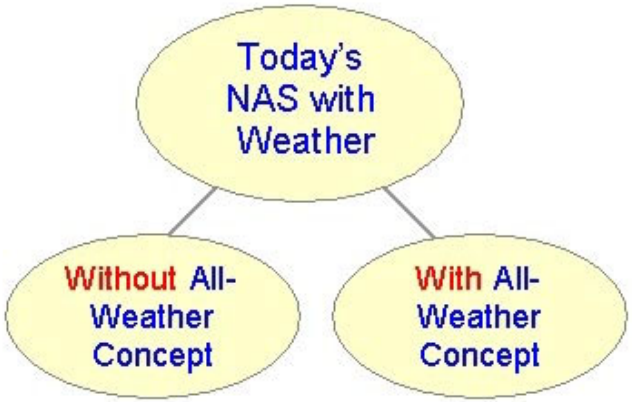


Benefit Mechanisms:

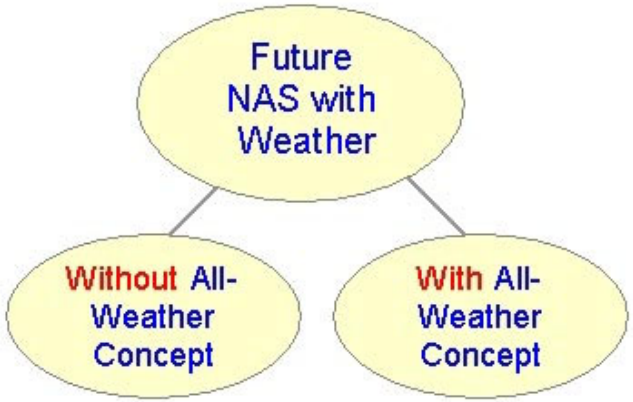
- More **accurate** take off time prediction and EDCT compliance
- Increased **safety** due to better predictions of aircraft trajectories clear of hazardous weather
- Increased airport and en route **throughput** through weather avoidance algorithms that dynamically adjust flows
- **User preferences** included in solutions
- Weather avoidance algorithms lead to **delay savings** that directly benefit the airlines schedule integrity
- **Equity** enforced through user preferences and DST solutions
- **Human factors** benefits from a common situation awareness and better human-computer interfaces
- Reduced **environmental emissions**

Approach to Self Assessment:

Reference point for capacity on a typical day in today's NAS



Benefit of the All-Weather Capacity-Increasing Concept if implemented in today's NAS



Benefit of the All-Weather Capacity-Increasing Concept if implemented in the future NAS

- **No Weather**
- **Typical Weather**
- **Severe Weather**
- **Rare Weather**

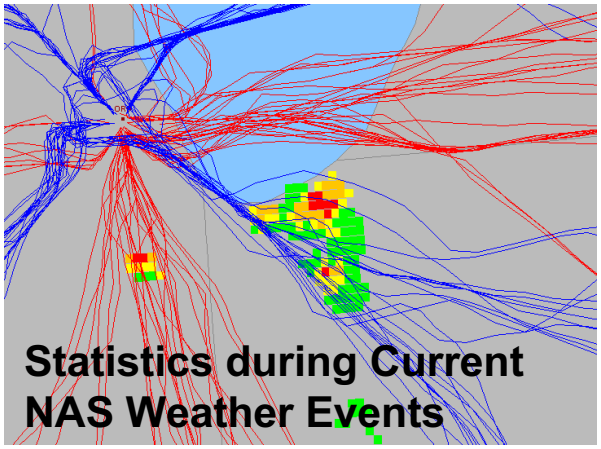
Metrics:

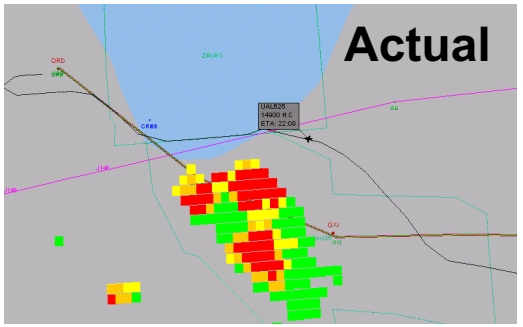
- **Define Metrics**
- **Select the Metrics that apply to the domain or type of experiment**
  - **Human-In-The-Loop (HITL)**
  - **Fast-Time**

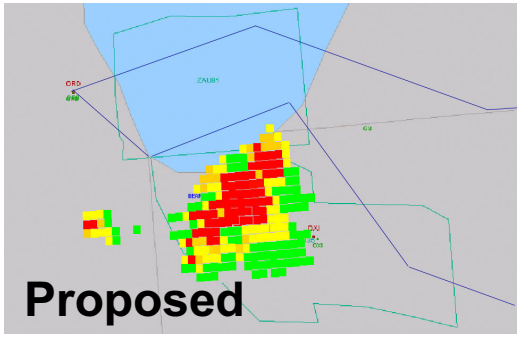
Metric	Category
Capacity	Airport Capacity
	En Route Sector Capacity
	NAS Capacity
	Throughput
Flexibility	User Preference
	Equity
Efficiency	Government, Airline, & Passenger Costs
	Airspace Utilization
Predictability	Time Variability
	EDCT Compliance
	Sector Demand
Safety	Weather Exposure
	Conflict Alerts
	Workload
Environment	Noise
	Pollution
Delay	Average Delay
	Average Block Time
Human	Human Performance
Factors	Human Behavior
	Preference Metrics

Self Assessment Comparisons:

- Select Domain of Interest (e.g, Transition to Metering Fix)
- Select Metrics
- Compare scenarios from today's NAS (2002) with/without concept Core Ideas and future NAS (2020)
- Investigate benefits for different types of days in the NAS (no weather to extreme weather) for tradeoffs







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Conclusions

- Weather poses Complex Constraints that affect each domain of the NAS differently, varying day by day
- The Core Ideas Required to address weather constraints:
  - Flexible Traffic Management Considering Weather Constraints
  - Prediction (Coupled Weather and Traffic Prediction)
  - Coordination and Information Transfer supporting a Shared Situation Awareness
- Self Assessment will proceed to demonstrate Core Ideas on different types of weather (typical, severe, rare) and for 2002 vs. 2020 over all domains of interest